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Ultraschall-Diagnosegerät

Appareil à diagnostic par ultrasons

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EP 0 509 760 B1

Description

Background of the Invention

1. Field of the Invention

The present invention relates to an ultrasonic diagnosis apparatus for radiating ultrasonic waves in a cross section of a subject by color Doppler scan, detecting the intensity of the reflected echo, and brightness-modulating the intensity of the reflected echo, thereby obtaining a tomogram of the subject, and also for detecting a frequency-deviation (Doppler shift) of the reflected echo and detecting the direction and flow velocity of a blood flow in the subject, thereby displaying the blood flow two-dimensionally by coloring the blood flow portion in the tomogram in accordance with the detected flow velocity and direction.

2. Description of the Related Art

This type of ultrasonic diagnosis apparatus is known as a color Doppler flow mapping apparatus, and in particular as a BDF apparatus, since it relates to blood flow imaging in a tomogram image (B-mode) display. A blood flow which approaches an ultrasonic probe is colored in red, a blood flow which moves away from the probe is colored in blue, and a turbulent flow is colored in green. The velocity of the blood flow is represented by brightness.

The BDF apparatus will now be described in brief. An ultrasonic Doppler method utilizes an ultrasonic Doppler shift wherein, when ultrasonic waves are reflected by a moving body, the frequency of the reflected waves shifts from a transmission frequency in proportion to the velocity of the object. Specifically, ultrasonic waves are radiated to a subject and the radiation direction is scanned in order to obtain a tomogram. In this case, ultrasonic pulses are transmitted repeatedly in respective directions in which ultrasonic waves are radiated, and a Doppler shift frequency is detected based on the phase variation of the reflected echoes. Thus, the data representing the movement of the moving body at a depth, at which the echo is reflected, is acquired. According to the ultrasonic Doppler method, it is possible to know the direction of the blood flow at a location in the subject and the condition of the blood flow (e.g. turbulent flow or regular flow).

In order to obtain blood flow data from an ultrasonic reflected echo signal, an ultrasonic probe is driven to repeatedly radiate ultrasonic waves in a raster direction for a number of times, and the received signal is detected by an orthogonal phase detecting circuit, thereby obtaining a Doppler shift signal on the basis of blood flow. Since a color Doppler image is obtained in real time, the Doppler shift signal is frequency-analyzed by a frequency analyzing circuit to find an average value of the Doppler shift, an average power of the Doppler shift, etc. A blood flow velocity color flow mapping (CFM) image is obtained by an auto-correlation circuit, etc., built in to the frequency analyzing circuit, and the blood flow velocity color flow mapping (CFM) image and a B-mode image are written in a digital scan converter (DSC). These images are read out from the digital scan converter (DSC) and the two-dimensional blood flow velocity CFM image is displayed on the B-mode image display on a TV monitor. Recently, this apparatus has been used to diagnose not only the heart but also those parts in which blood flow velocity is low, for example, blood vessels in the abdomen or peripheral blood vessels.

In the conventional color Doppler scan, the CFM scanning frame rate is equal to the B-mode scanning frame rate. Figs. 1(A) and 1(B) show a first example of a conventional color Doppler scanning pattern. Fig. 1(A) shows 120 rasters, addressed 0th to 119th. For a B-mode scan, ultrasonic pulses are transmitted and ultrasonic data are received only 1 time for each raster. For a CFM scan, ultrasonic pulses are transmitted and ultrasonic data are received 16 times for each raster. In Fig. 1(B), the 0th raster is scanned 1 time by B-mode scan, and then the 0th raster is scanned continuously 16 times by CFM scan. Next, the 1st raster is scanned 1 time by B-mode scan, and then the 1st raster is scanned continuously 16 times by CFM scan. Then, in the same manner, the 2nd to 119th rasters are continuously scanned by B-mode scan and CFM scan. Thus, 1 frame of data for displaying a CFM image and a B-mode image is acquired. If the ultrasonic pulse repetition frequency (PRF) for transmitting ultrasonic pulse is 5 KHz, this first example's scanning frame rate FR1 is calculated as follows.

$$FR1 = (5X10^{3}) / (120X1+120X16) = 2.45 \text{ (frames / 1 second)}$$

This scanning frame rate FR1 is for B-mode scan and CFM scan, and then the B-mode display frame rate is equal to the CFM display frame rate.

Figs. 2(A) and 2(B) show a second example of a conventional color Doppler scanning pattern. Fig. 2(A) shows 120 rasters, addressed 0th to 118th and 1 dummy raster. For a B-mode scan, ultrasonic data are transmitted and received only 1 time for each raster. For a CFM scan, ultrasonic data are transmitted and received 16 times for each alternate raster (a total 60 rasters) for collecting CFM image data. In Fig. 2(B), first, the 0th raster is scanned 1 time by B-mode scan, and then the 0th raster is scanned continuously 16 times by CFM scan. Next, the 1st and 2nd rasters are scanned 1 time for each by the B-mode scan, and then the 2nd raster is scanned continuously 16 times by the CFM scan. Then,

the 3rd to 119th rasters are scanned by B-mode scan and CFM scan as described above. Thus, 1 frame of data for displaying CFM image and B-mode image is acquired. If the PRF for transmitting the ultrasonic pulse is 5 KHz, this second example's scanning frame rate FR2 is calculated as follows.

$$FR2 = (5X10^3) / (120X1+60X16) = 4.63 \text{ (frames / 1 second)}$$

This scanning frame rate FR2 is for B-mode scan and CFM scan, and then the B-mode display frame rate is equal to the CFM display frame rate.

Figs. 3(A) and 3(B) show a third example of a conventional color Doppler scanning pattern, disclosed in United States Patent No. 4,993,417. Fig. 3(A) shows 120 rasters, addressed 0th to 118th and 1 dummy raster. For a B-mode scan, each raster transmits and receives ultrasonic data only 1 time for collecting the B-mode image data. For a CFM scan, each alternate raster (a total 60 rasters) transmits and receives ultrasonic data 16 times for collecting the CFM image data. In Fig. 3(B), the 0th and 2nd rasters are alternately scanned 16 times for each by CFM scan. Next, the 0th to 3rd rasters are scanned 1 time for each by B-mode scan. Then, as described above, the 4th to the 119th rasters are scanned by B-mode scan and CFM scan. Thus, 1 frame data for displaying a CFM image and a B-mode image is acquired. If PRF for transmitting ultrasonic pulse is 5 KHz, this third example's scanning frame rate FR3 is calculated as follows.

$$FR3 = (5X10^3) / (120X1+60X16) = 4.63 \text{ (frames / 1 second)}$$

This scanning frame rate FR3 is for B-mode scan and CFM scan, and then the B-mode display frame rate is equal to the CFM display frame rate. This third examples' CFM scanning rate for each raster is 2 times longer than the second example's CFM scanning rate for each raster, therefore a lowest and a highest velocity of blood flow detected by the third examples' scanning pattern can be 50 percent slower than by the second examples' scanning pattern. Then, it is possible to observe slower velocity of blood flow by the third example than the second example.

Figs. 4(A) and 4(B) show a fourth example of a conventional color Doppler scanning pattern, related to United States Patent No. 4,993,417. Fig. 4(A) shows 120 rasters, addressed 0th to 118th and 1 dummy raster. For a B-mode scan, ultrasonic data are transmitted and received only 1 time for each raster. For a CFM scan, ultrasonic data are transmitted and received 16 times for each alternate raster (total 60 rasters) for collecting CFM image data. In Fig. 4(B), first, the 2nd and 0th rasters are alternately scanned 6 times for each by CFM scan. Next, the 2nd raster is scanned 1 time by CFM scan, then the 0th raster is scanned 1 time by B-mode scan, then the 2nd raster is scanned 1 time by CFM scan, then 1st raster is scanned 1 time by B-mode scan. Next, the 2nd and 4th rasters are alternately scanned 8 times for each by CFM scan. Then, as described above, all rasters are scanned by B-mode scan and CFM scan in the same pattern. Thus, 1 frame of data for displaying a CFM image and a B-mode image is acquired. If the PRF for transmitting the ultrasonic pulse is 5 KHz, this second example's scanning frame rate FR4 is calculated as follows.

$$FR4 = (5X10^3) / (120X1+60X16) = 4.63 \text{ (frames / 1 second)}$$

This scanning frame rate FR4 is for the B-mode scan and the CFM scan, and then the B-mode display frame rate is equal to the CFM display frame rate. This fourth example's scanning pattern is able to collect and output B-mode image data and CFM image data at same the intervals for each raster.

These conventional BDF apparatuses, however, have the following problem. As stated above, the B-mode scanning frame rate is equal to the CFM scanning frame rate, and the CFM scan needs a longer time to collect the image data for each raster than the B-mode scan, therefore the B-mode frame rate is dependent on the CFM frame rate. For example, when the ultrasonic probe is moved on a subject during scanning by color Doppler scan, the amount of change caused in the B-mode image as a result of time direction changes and space direction changes is bigger than the amount of change in the CFM image. This is because the resolutional ability of the B-mode image is far higher than that of the CFM image. Thus, the ability of the B-mode image display depends on the B-mode frame rate. In other words, the B-mode frame rate generated by a color Doppler scan is dependent on the CFM frame rate. Therefore, the B-mode frame rate generated by a color Doppler scan is too slow compared to the B-mode frame rate generated by a B-mode scan, and it is thus more difficult to diagnose from a B-mode image by the color Doppler scan than from a B-mode image by the B-mode scan.

Summary of the Invention

It is an object of the present invention to provide an ultrasonic diagnosis apparatus capable of improving the ability to use images developed by a B-mode image display using a color Doppler scan.

In order to achieve the above object, according to the present invention, there is provided an ultrasonic diagnosis apparatus for displaying an ultrasonic image, which image is obtained by data from a plurality of rasters scanned by an

ultrasonic imaging transducer, comprising:

transducer means;
B-mode scanning means for scanning each raster by controlling the transducer means such that the transducer means transmits an ultrasonic pulse and receives a reflected echo from each raster;
CFM scanning means for scanning each raster by controlling the transducer means such that the transducer means transmits plural ultrasonic pulses and receives plural reflected echoes from each raster;
B-mode imaging means for calculating an intensity data from the reflected echo scanned by the B-mode scanning means for each raster, and for producing a tomogram image as a B-mode frame from the intensity data calculated in a plurality of rasters;
CFM imaging means for calculating a Doppler shift data from the reflected echoes scanned by the CFM scanning means for each raster, and for producing a color flow mapping image as a CFM frame from the Doppler shift data calculated in the plurality of rasters;
display means for displaying the color flow mapping image on the tomogram image; and
scan controlling means for independently controlling a first scanning frame rate used by the B-mode scanning means for scanning the B-mode frame and a second scanning frame rate used by the CFM scanning means for scanning the CFM frame, wherein the first scanning frame rate used by the B-mode scanning means for scanning the B-mode frame is higher than the second scanning frame rate used by the CFM scanning means for scanning the CFM frame.

According to the ultrasonic diagnosis apparatus of the present invention, the B-mode scanning frame rate may be controlled so that it is higher than the CFM scanning frame rate. Therefore, the realtime following ability for displaying B-mode image is improved from the conventional color Doppler scan.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate a presently preferred embodiment of the invention, and the detailed description of the preferred embodiment given below serves to explain the principles of the invention.

Figs. 1(A) and 1(B) show the first example of a conventional color Doppler scanning pattern;
Figs. 2(A) and 2(B) show the second example of a conventional color Doppler scanning pattern;
Figs. 3(A) and 3(B) show the third example of a conventional color Doppler scanning pattern;
Figs. 4(A) and 4(B) show the fourth example of a conventional color Doppler scanning pattern;
Fig. 5 is a block diagram showing an ultrasonic diagnosis apparatus according to the present invention;
Fig. 6 is a block diagram showing in detail a B-mode processor according to the present invention;
Fig. 7 is a block diagram showing in detail a MTI processor according to the present invention;
Fig. 8 is a block diagram showing in detail a blood flow data according to the present invention;
Fig. 9 is a block diagram showing in detail an interpolation circuit according to the present invention;
Figs. 10(A) and 10(B) show the first example of the invention's color Doppler scanning pattern;
Fig. 11 shows a comparison between B-mode scanning frames and CFM scanning frames for the first example of the invention's color Doppler scan;
Figs. 12(A) and 12(B) show the second example of the invention's color Doppler scanning pattern;
Figs. 13(A) and 13(B) show the third example of the invention's color Doppler scanning pattern;
Fig. 14 shows the relationship between raster addresses and scanning timing for the third example of the invention's color Doppler scan.
Figs. 15(A) and 15(B) show the fourth example of the invention's color Doppler scanning pattern;
Fig. 16 shows the relationship between raster addresses and scanning timing for the fourth example of the invention's color Doppler scan.
Figs. 17(A) and 17(B) show the fifth example of the invention's color Doppler scanning pattern; and
Figs. 18(A) and 18(B) show the sixth example of the invention's color Doppler scanning pattern.

Detailed Description of the Preferred Embodiments

An ultrasonic diagnosis apparatus according to an embodiment of the present invention will be described below

with reference to the accompanying drawings.

In Fig. 5, a scanning circuit 12 is connected to an electronic sector scanning type ultrasonic probe 10. A probe 10 comprises a large number of piezoelectric transducers arrayed in a row. By varying the timing of voltages applied to the respective transducers, it is possible to cause ultrasonic beams to scan a sector or to focus the ultrasonic beams. The probe 10 need not be limited to the electronic sector scanning type and it may be of a linear scanning type or a mechanical scanning type.

In the scanning circuit 12, an output of an oscillator 14, which determines an oscillation frequency of the transducers, is applied to the probe 10 via a transmitting delay circuit 16 and a pulse generator 18. The pulse generator 18 periodically supplies the probe 10 with driving pulses. The inverse of the period is the repetition frequency (rate frequency) of the ultrasonic beams. By varying the delay times of the delay circuit 16, it becomes possible to vary the directions of the ultrasonic pulses transmitted to a subject from the probe 10. The delay times are controlled by control signals from a controller 40.

An output from the probe 10 is supplied to an adder 22 through a preamplifier 20 and a receptive delay circuit 17. The delay circuit 17 comprises a large number of delay lines having variable delay times. By varying the delay times of the respective delay lines, it becomes possible to vary the directions (raster directions) of the ultrasonic pulses received from the subject by the probe 10. The delay times are controlled by control signals from the controller 40. In order to detect a B-mode image (tomogram image), it is necessary to transmit and receive a ultrasonic pulse in the same raster direction. In order to detect a color flow mapping (CFM) image, it is necessary to transmit and receive ultrasonic pulses in the same raster direction for several times.

The controller 40, connected from an operation switch 36, controls scan-timings for B-mode scanning and CFM scanning independently, and thus the frame rate for B-mode scanning and for CFM scanning are controlled independently. Therefore, the controller 40, in this embodiment, can control the system so that the frame rate for B-mode scanning is higher than the frame rate for CFM scanning.

An output, obtained by B-mode scan, from the adder 22 is input to a B-mode processor 24, and the intensity of the reflected ultrasonic echo in each raster direction is detected. The B-mode processor 24 has a structure as shown in Fig. 6, and comprises a logarithmic amplifier 72, an envelope detector 74 and A/D converter 76. The logarithmic amplifier 72 logarithmic-amplifies a received signal output from the adder 22, and the envelope detector 74 detects an envelope of the signal from the amplifier 72. An output from B-mode processor 24 is input to a first digital scan converter (DSC) 25 as brightness data of each raster, that is, B-mode image (tomogram) data. The raster of the ultrasonic probe 10 is changed in a sectional fashion, but the raster of a color monitor (display) 46 is lateral, as in a standard TV system. Thus, the DSC 25 alters the raster direction (scan direction) of the input image and outputs the resultant image.

An output, obtained by CFM scan, from the adder 22 and an output from the oscillator 14 are supplied to a Doppler detector 28. The Doppler detector 28 is a circuit for detecting the Doppler shift frequency by an orthogonal detection method. The Doppler detector 28 comprises mixers 30a and 30b, a 90° phase shifter 32, and low-pass filters (LPF) 34a and 34b. An output from the adder 22 is multiplied by an output from the oscillator 14 in the mixer 30a and the output from the adder 22 is multiplied by an output from the phase shifter 32 in the mixer 30b. Each of the mixers 30a and 30b outputs a signal containing a Doppler shift frequency component and a high-frequency component (double the transmission frequency). The LPFs 34a and 34b remove the high-frequency component and a sine component of the Doppler shift frequency. The Doppler shift frequency is then provided to two channels for the cosine and sine components, in order to detect the polarity of shift frequency.

The output from the Doppler detector 28 is supplied to an MTI (Moving Target Indicator) processor 38 for color flow mapping (CFM) image. Fig. 7 is a block diagram showing the MTI processor 38 in detail. The outputs from the LPFs 34a and 34b are supplied to an auto-correlation calculation circuit 54 through A/D converters 50a and 50b and MTI filters 52a and 52b. The auto-correlation calculation circuit 54 is employed to perform, in real time, frequency analysis of many points distributed two-dimensionally. Compared to an FFT (Fast Fourier Transform) process, the number of arithmetic operations decreases. The output from the auto-correlation calculation circuit 54 is supplied to a mean velocity calculation circuit 56, a variance calculation circuit 58, and a power calculation circuit 60. The outputs from the calculation circuits 56, 58 and 60 are supplied to a second DSC 26. Thus, the MTI processor 38 can acquire blood flow data at each point on a tomogram obtained by the B-mode processor 24.

The MTI filters 52a and 52b function to remove unnecessary reflected echoes (clutter component) from a stationary reflector (blood vessel wall, heart wall, etc.). The filters 52a and 52b comprise digital filters having low-pass characteristics. Specifically, the MTI filters 52a and 52b detect the movement of blood flow on the basis of the phase variation, with respect to the same pixel, between the echo signals obtained from several different ultrasonic radiations in the same raster direction, and remove the clutter component. Alternatively, the MTI filters may have an analog construction and be composed of delay lines and subtracters for subtracting, from the reflected signals, the reflected signals obtained after a predetermined time period, thereby removing the clutter component.

A mean value v of the Doppler shift frequency, a variance σ^2, and total power TP respectively output from the mean velocity calculation circuit 56, variance calculation circuit 58, and power calculation circuit 60 are supplied to the DSC 26 for blood flow data. The total power TP is proportional to the intensity scattered echo from the blood flow, but an echo

from a moving body having a frequency not higher than the cut-off frequency of the MTI filters 52a and 52b is removed. Like the DSC 25, the DSC 26 alters the scanning direction of the input blood flow data and outputs the resultant data, and, where necessary, performs frame interpolation. The details of the DSC 26 will be described later.

Control signals from the controller 40 are also supplied to the MTI processor 38, DSC 25 and DSC 26. The monochromatic tomogram and blood flow data, which are output from the DSCs 25 and 26, are supplied to a color processing circuit 42. As in the conventional art, the blood flow portion in the tomogram is colored such that the direction of the blood flow towards the probe is expressed in red, the direction away from the probe is in blue, the mean velocity is in brightness, and the velocity distribution is expressed by hues (mixed with green), thereby producing a color Doppler image. The output from the color processing circuit 42 is supplied to display 46 through a D/A converter 44. Though not shown, the output from the D/A converter 44 may be supplied to a recording section such as a VTR, as well.

Fig. 8 is a block diagram showing in detail the second DSC 26 for blood flow data. The DSC 26 comprises three frame memories 80a, 80b, and 80c, multiplexers (MUX) 82 and 84 functioning as control means, and an interpolation circuit 88 functioning as interpolation means. The first DSC 25 for tomogram data has the same construction as the second DSC 26, except that the interpolation circuit 88 is omitted.

The three frame memories 80a to 80c are controlled by control signals from the controller 40, and store blood flow data supplied successively in units of a frame. The blood flow data of each frame is successively written in the frame memories 80a to 80c. While one frame memory is set in the write mode, the other two frame memories are set in the read mode. Thus, the blood flow data of the same frame is read from each frame memory for a two-frame period. The outputs from the frame memories 80a to 80c are supplied to the three-inputs/two-outputs multiplexer 82. The multiplexer 82 delivers the outputs of the frame memories set in the read mode as first and second output signals F1 and F2. Thus, the output signals F1 and F2 of the multiplexer 82 are, respectively, the data of the second frame prior to the presently written frame, and the data of the first frame prior to the present frame, i.e., the prior frame. For example, in the period in which the third-frame data is written in the frame memory 80c, the first frame and the second frame data read out from the frame memories 80a and 80b, and the read-out data are output from the multiplexer 82 as first and second signals F1 and F2.

The two outputs from the multiplexer 82 are supplied to a three-inputs/one-output multiplexer 84 and an interpolation circuit 88. The output from the interpolation circuit 88 is supplied to a third input terminals of the multiplexer 84. The interpolation circuit 88 interpolates the flow velocity data of an intermediate frame based on the flow velocity data F1 and F2 of the second and first frames prior to the present frame. The interpolation circuit 88 has a structure, for example, as shown in Fig. 9. The flow velocity data F1 and F2 are multiplied by a coefficient by multipliers 100 and 102, and the multiplied values are added by an adder 104. The added result F3 are supplied to the multiplexer 84 as interpolation flow velocity data. Then, several number of interpolated imaging frames between the two scanned CFM imaging frames are obtained by changing the coefficient. By frame interpolating the CFM image, the display frame rate thereof can be several times. In this embodiment, the number of interpolated CFM imaging frames between two scanned CFM imaging frames is determined by comparing the scanning frame rate for B-mode scanning with the CFM scanning rate.

Next, the scanning patterns of the apparatus of the present invention will be described.

Figs. 10(A) and 10(B) show a first example of a color Doppler scanning pattern of this invention. Fig. 10(A) shows 120 rasters, addressed 0th to 119th. For a B-mode scan, ultrasonic data are only transmitted and received 1 time for each raster. For a CFM scan, ultrasonic data are transmitted and received 16 times for each raster. In Fig. 10(B), the 0th to 3rd rasters are each scanned 1 time by B-mode scan, and then the 0th raster is scanned continuously 16 times by CFM scan. Next, the 4th to 7th rasters are each scanned 1 time by B-mode scan, and then the 1st raster is scanned continuously 16 times by CFM scan. Then alternately, as described above, 4 rasters are scanned by B-mode scan and 1 raster is scanned by CFM scan. Therefore, 30 rasters are scanned by CFM scan while 120 rasters (1 frame) are scanned by B-mode scan, and 4 frames (120X4 rasters) are scanned by B-mode scan while 1 frame is scanned by CFM scan. Thus, one frame of data for displaying a CFM image and a B-mode image is acquired. If the PRF for transmitting the ultrasonic pulse is 5 KHz, the B-mode scanning frame rate BFR1 and the CFM scanning frame rate CFR1 in this first embodiment are calculated as follows.

$$BFR1 = (5X10^3) / (120X\,1+ 30X16) = 8.33 \text{ (frames / 1 second)}.$$

$$CFR1 = (5X10^3) / (120X16+120X\,4) = 2.08 \text{ (frames / 1 second)}$$

This means that the B-mode scanning frame rate BFR1 is about 4 times (= 8.33/2.08) higher than the CFM scanning frame rate CFR1, and the BFR1 is about 3.4 times higher than the B-mode frame rate FR1 (= 2.45) of the conventional color Doppler scan and the CFR1 is about equal to the CFM frame rate FR1 of the conventional color Doppler scan in Fig. 1. Therefore, the realtime following ability for displaying B-mode image is 3.4 times improved from the conventional color Doppler scan. Then, three interpolated CFM imaging frames, produced by DSC 26, are inserted between two scanned CFM imaging frames as shown in Fig. 11, and the CFM images are displayed on the scanned B-mode images on display 46.

Figs. 12(A) and 12(B) show second example of a color Doppler scanning pattern according to the invention. Fig. 12(A) shows 120 rasters, addressed 0th to 118th and 1 dummy raster. For a B-mode scan, ultrasonic data are transmitted and received only 1 time for each raster for collecting B-mode image data. For a CFM scan, ultrasonic data are transmitted and received 16 times for each alternate raster (total 60 rasters) for collecting CFM image data. In Fig. 12(B), first, the 0th to 3rd rasters are each scanned 1 time by B-mode scan, and then the 0th raster is scanned continuously 16 times by CFM scan. Next, the 4th and 7th rasters are each scanned 1 time by B-mode scan, and then the 2nd raster is scanned continuously 16 times by CFM scan. Then alternately, as described above, 4 rasters are scanned by B-mode scan and 1 raster is scanned by CFM scan. Therefore, 30 rasters are scanned by CFM scan while 120 rasters (1 frame) are scanned by B-mode scan, and 2 frames (120X2 rasters) are scanned by B-mode scan while 1 frame (60 rasters) are scanned by CFM scan. Thus, one frame of data for displaying a CFM image and a B-mode image is acquired. If the PRF for transmitting the ultrasonic pulse is 5 KHz, the B-mode scanning frame rate BFR2 and the CFM scanning frame rate CFR2 in this second embodiment are calculated as follows.

$$BFR2 = (5X10^3) / (120X\,1+ 30X16) = 8.33 \text{ (frames / 1 second)}$$

$$CFR2 = (5X10^3) / (60X16+120X\,2) = 4.17 \text{ (frames / 1 second)}$$

This means that the B-mode scanning frame rate BFR2 is about 2 times (= 8.33/4.17) higher than the CFM scanning frame rate CFR2, and the BFR2 is about 1.8 times higher than the B-mode frame rate FR2 (= 4.63) of the conventional color Doppler scan and the CFR2 is about 0.9 times higher than the CFM frame rate FR2 of the conventional color Doppler scan in Fig. 2. Therefore, the realtime following ability for displaying B-mode image is 1.8 times improved from the conventional color Doppler scan. One interpolated CFM imaging frame, produced by DSC 26, is inserted between two scanned CFM imaging frames, and the CFM images are displayed on the scanned B-mode images on display 46.

Figs. 13(A) and 13(B) show a third example of a color Doppler scanning pattern according to this invention. Fig. 13(A) shows 120 rasters, addressed 0th to 118th and 1 dummy raster. For a B-mode scan, ultrasonic data are transmitted and received 1 time for each raster for collecting B-mode image data, and for a CFM scan, ultrasonic data are transmitted and received 16 times for each alternate raster (total 60 rasters) for collecting CFM image data. In Fig. 13(B), the 0th and 2nd rasters are alternately scanned 16 times for each by CFM scan, and then the 0th to 7th rasters are scanned 1 time for each by B-mode scan. Next, the 4th and 6th rasters are alternately scanned 16 times for each by CFM scan, and then the 8th to 15th rasters are scanned 1 time for each by B-mode scan. Then alternately, as described above, alternate rasters are scanned by CFM scan and 8 rasters are scanned by B-mode scan as shown in Fig. 13(B). Therefore, 30 rasters are scanned by CFM scan while 120 rasters (1 frame) are scanned by B-mode scan, and 2 frames (120X2 rasters) are scanned by B-mode scan while 1 frame (60 rasters) is scanned by CFM scan.

This scanning method is called interleave scan, and a chart of this scan-timing and raster addresses are shown in Fig. 14. In Fig. 14, a black dot (●) shows a timing for CFM scanning, and a white dot (○) shows a timing for B-mode scanning. In this interleave scan, the CFM scanning rate for each raster is two times lower than the rate of the scanning method shown in Fig. 12, therefore it can detect two times slower velocity of blood flow than the method illustrated by the scanning method illustrated in Fig. 12. If n (n >= 2) rasters are alternately scanned 16 times each by the CFM scan, it can detect n times slower velocity of blood flow than can be detected by the scanning method of Fig. 13.

Thus, one frame data for displaying a CFM image and a B-mode image is acquired. If the PRF for transmitting the ultrasonic pulse is 5 KHz, the B-mode scanning frame rate BFR3 and the CFM scanning frame rate CFR3 in this third embodiment are calculated as follows.

$$BFR3 = (5X10^3) / (120X\,1+ 30X16) = 8.33 \text{ (frames / 1 second)}$$

$$CFR3 = (5X10^3) / (60X16+120X\,2) = 4.17 \text{ (frames / 1 second)}$$

This means that the B-mode scanning frame rate BFR3 is about 2 times (= 8.33/4.17) higher than the CFM scanning frame rate CFR3, and the BFR3 is about 1.8 times higher than the B-mode frame rate FR2 (= 4.63) of the conventional color Doppler scan and the CFR3 is about 0.9 times higher than the CFM frame rate FR3 of the conventional color Doppler scan in Fig. 3. Therefore, the realtime following ability for displaying B-mode image is 1.8 times improved from the conventional color Doppler scan. One interpolated CFM imaging frame, produced by DSC 26, is inserted between two scanned CFM imaging frames, and the CFM images are displayed on the scanned B-mode images on display 46.

Figs.15(A) and 15(B) show a fourth example of a color Doppler scanning pattern according to this invention. Fig. 15(A) shows 120 rasters, addressed 0th to 118th and 1 dummy raster. For a B-mode scan, ultrasonic data are transmitted and received only 1 time for each raster for collecting B-mode image data. For a CFM scan, ultrasonic data are transmitted and received 16 times for each alternate raster (total 60 rasters) for collecting CFM image data. In Fig. 15(B), first, the 2nd and 0th rasters are alternately scanned 6 times each by CFM scan. Next, the 2nd raster is scanned 1 time by CFM scan, then the 0th raster is scanned 1 time by B-mode scan, then the 2nd raster is scanned 1 time by

CFM scan, then 1st raster is scanned 1 time by B-mode scan, then the 2nd raster is scanned 1 time by CFM scan, then 2nd raster is scanned 1 time by B-mode scan, then 2nd raster is scanned 1 time by CFM scan, then 3rd raster is scanned 1 time by B-mode scan. Then the 2nd and 4th rasters are alternately scanned 6 times each by CFM scan. Then, as described above, all rasters are scanned by B-mode scan and CFM scan as shown in Fig. 15(B). Therefore, 30 rasters are scanned by CFM scan while 120 rasters (1 frame) are scanned by B-mode scan, and 2 frames (120X2 rasters) are scanned by B-mode scan while 1 frame (60 rasters) is scanned by CFM scan.

This scanning method is called interleave scan, and a chart of this scan-timing and raster addresses are shown in Fig. 16. In Fig. 16, a black dot (●) shows a timing for CFM scanning, and a white dot (○) shows a timing for B-mode scanning. In this interleave scan, the CFM scanning rate for each raster is two times lower than the rate by scanning method in Fig. 12, therefore it can be detected two times slower velocity of blood flow than can be detected by the scanning method in Fig. 12. Then, in this interleave scan, it is equal for each raster that the period for correcting 16 data by CFM scan.

Thus, one frame of data for displaying a CFM image and a B-mode image is acquired. If the PRF for transmitting the ultrasonic pulse is 5 KHz, the B-mode scanning frame rate BFR4 and the CFM scanning frame rate CFR4 in this fourth embodiment are calculated as follows.

$$BFR4 = (5X10^3) / (120X\,1+ 30X16) = 8.33 \text{ (frames / 1 second)}$$

$$CFR4 = (5X10^3) / (60X16+120X\,2) = 4.17 \text{ (frames / 1 second)}$$

This means that the B-mode scanning frame rate BFR4 is about 2 times (= 8.33/4.17) higher than the CFM scanning frame rate CFR4, and the BFR4 is about 1.8 times higher than the B-mode frame rate FR4 (= 4.63) of the conventional color Doppler scan and the CFR4 is about 0.9 times higher than the CFM frame rate FR4 of the conventional color Doppler scan in Fig. 4. Therefore, realtime following ability for displaying B-mode image is 1.8 times improved from the conventional color Doppler scan. One interpolated CFM imaging frame, produced by DSC 26, is inserted between two scanned CFM imaging frames, and the CFM images are displayed on the scanned B-mode images on display 46.

Figs. 17(A) and 17(B) show a fifth example of a color Doppler scanning pattern according to this invention. Fig. 17(A) shows 124 rasters, addressed 0th to 120th and 3 dummy rasters (not shown). For a B-mode scan, ultrasonic data are transmitted and received 1 time for each raster for collecting B-mode image data. For a CFM scan, ultrasonic data are transmitted and received 16 times for each alternate 4 raster intervals (total 30 rasters) for collecting CFM image data. In Fig. 17(B), first, the 0th raster is scanned 1 time by B-mode scan, and then the 0th raster is scanned 1 time by CFM scan. Next, the 1st raster is scanned 1 time by B-mode scan, and then the 0th raster is scanned 1 time by CFM scan. Then alternately, as described above, the rasters are scanned by B-mode scan and CFM scan as shown in Fig. 17(B). Therefore, there are 124 CFM scans while 124 rasters (1 frame) are scanned by B-mode scan, and 30X16 rasters are scanned by the B-mode scan while 1 frame (30X16 rasters) are scanned by CFM scan. Thus, one frame of data for displaying CFM image and B-mode image is acquired. If the PRF for transmitting the ultrasonic pulse is 5 KHz, the B-mode scanning frame rate BFR5 and the CFM scanning frame rate CFR5 in this fifth embodiment are calculated as follows.

$$BFR5 = (5X10^3) / (124 + 124) = 20.16 \text{ (frames / 1 second)}$$

$$CFR5 = (5X10^3) / (30X16+30X16) = 5.21 \text{ (frames / 1 second)}$$

This means that the B-mode scanning frame rate BFR5 is about 3.9 times (= 20.16/5.21) higher than the CFM scanning frame rate CFR5. In this scan, the CFM scanning rate for each raster is two times lower than the rate by scanning method in Fig. 12, therefore it can detect two times slower velocity of blood flow than could be detected by the scanning method illustrated in Fig. 12.

Figs. 18(A) and 18(B) show a sixth example of a color Doppler scanning pattern according to this invention. Fig. 18(A) shows 120 rasters, addressed 0th to 119th. For a B-mode scan, ultrasonic data are transmitted and received only 1 time for each raster for collecting B-mode image data. For a CFM scan, ultrasonic data are transmitted and received 16 times for each raster (total 120 rasters) for collecting CFM image data. In Fig. 18(B), first, the 0th raster is scanned 1 time by B-mode scan, and then the 0th raster is scanned 16 times by CFM scan. Next, the 1st raster is scanned 1 time by B-mode scan, and then the 1st raster is scanned 16 times by CFM scan. Then alternately, as described above, the 2nd to the 119th rasters are scanned by B-mode scan and CFM scan in the first frame. Next, in the second frame, the 0th to the 119th rasters are scanned by B-mode scan only. Next, in the third frame, the 0th to the 119th rasters are alternately scanned are 1 time each by B-mode scan and 16 times each scanned by CFM scan, as in the first frame. Thus, each frame of data is acquired. If the PRF for transmitting the ultrasonic pulse is 5 KHz, the B-mode scanning frame rate BFR6 and the CFM scanning frame rate CFR6 in this sixth embodiment are calculated as follows.

$$BFR6 = (5X10^3)/(120+120X16 + 120)X2 = 4.63(\text{frames} / 1 \text{ second})$$

$$CFR6 = (5X10^3)/(120+120X16 + 120) = 2.31(\text{frame} / 1 \text{ second})$$

This means that the B-mode scanning frame rate BFR6 is 2 times higher than the CFM scanning frame rate CFR6, and the BFR6 is about 1.9 times higher than the B-mode frame rate FR1 (= 2.45) of the conventional color Doppler scan and the CFR6 is about equal to the CFM frame rate FR1 of the conventional color Doppler scan. Therefore, the realtime following ability for displaying a B-mode image is improved from the conventional color Doppler scan. Then, one interpolated CFM imaging frame, produced by DSC 26, is inserted between two scanned CFM imaging frames, and the CFM images are displayed on the scanned B-mode images on display 46.

Generally said, the color Doppler scan of this invention provided that the period for scanning N frames (N >= 2) by B-mode scan and the period for scanning M frame(s) (1 <= M < N) by CFM scan are equal.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, and representative devices, shown and described. Accordingly various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and there equivalents.

Claims

1. An ultrasonic diagnosis apparatus for displaying an ultrasonic image, which image is obtained by data from a plurality of rasters scanned by an ultrasonic imaging transducer, comprising:

   transducer means (10);
   B-mode scanning means (12) for scanning each raster by controlling the transducer means (10) such that the transducer means (10) transmits an ultrasonic pulse and receives a reflected echo from each raster;
   colour flow mapping CFM scanning means (12) for scanning each raster by controlling the transducer means (10) such that the transducer means (10) transmits plural ultrasonic pulses and receives plural reflected echoes from each raster;
   scan controlling means (40) for controlling the B-mode scanning means (12) and the CFM scanning means (12);
   B-mode imaging means (24) for calculating an intensity data from the reflected echo scanned by the B-mode scanning means (12) for each raster, and for producing a tomogram image as a B-mode frame from the intensity data calculated in the plurality of rasters;
   CFM imaging means (38) for calculating a Doppler shift data from the reflected echoes scanned by the CFM scanning means (12) for each raster, and for producing a color flow mapping image as a CFM frame from the Doppler shift data calculated in the plurality of rasters; and
   display means (46) for displaying the color flow mapping image on the tomogram image, characterized in that:
   the scan controlling means (40) independently controls a first scanning frame rate used by the B-mode scanning means (12) for scanning the B-mode frame and a second scanning frame rate used by the CFM scanning means (12) for scanning the CFM frame, wherein the first scanning frame rate used by the B-mode scanning means (12) for scanning the B-mode frame is higher than the second scanning frame rate used by the CFM scanning means (12) for scanning the CFM frame.

2. An apparatus according to claim 1, further comprising interpolating means (88) for interpolating a frame of the color flow mapping image from data used to produce on earlier frame of the color flow mapping image.

3. An apparatus according to claim 2, wherein the display means (46) alternately displays the color flow mapping image produced by the CFM imaging means (38) and the interpolated color flow mapping image produced by the interpolating means (88).

4. An apparatus according to any proceeding claim wherein said scan controlling means (40) interleaves CFM scanning rasters between B-mode scanning rasters.

5. An apparatus as claimed in any preceding claim, wherein the scan controlling means (40) independently controls a period for scanning N frames (N>=2) by the B-mode scanning means (12) and a period for scanning M frames (I<=M<N) by the CFM scanning means (12) so that the period for scanning N frames by the B-mode scanning means (12) and the period for scanning M frames by the CFM scanning means (12) are equal.

Patentansprüche

1. Ultraschall-Diagnosegerät zum Anzeigen eines Ultraschall-Bildes, wobei das Bild aus Daten von einer Anzahl von Rastern erzeugt wird, die von einem Ultraschall-Bildsynthesewandler abgetastet werden, mit:

   einer Wandlereinrichtung (10);
   einer B-Mode-Abtasteinrichtung (12) zum Abtasten jedes Rasters, indem die Wandlereinrichtung (10) so gesteuert wird, daß die Wandlereinrichtung (10) einen Ultraschall-Impuls aussendet und von jedem Raster ein reflektiertes Echo empfängt;
   einer Farb-Strömung-Abbildung CFM-Abtasteinrichtung (12) zum Abtasten jedes Rasters, indem die Wandlereinrichtung (10) so gesteuert wird, daß die Wandlereinrichtung (10) mehrere Ultraschall-Impulse aussendet und von jedem Raster mehrere reflektierte Echos empfängt;
   einer Abtast-Steuerungseinrichtung (40) zur Steuerung der B-Mode-Abtasteinrichtung (12) und der CFM-Abtasteinrichtung (12);
   einer B-Mode-Bildsyntheseeinrichtung (24) zum Berechnen von Intensitätsdaten aus dem reflektierten Echo, das für jedes Raster von der B-Mode-Abtasteinrichtung (12) abgetastet wird, und zum Erzeugen eines Tomogramm-Bildes als ein B-Mode-Teilbild aus den Intensitätsdaten, die in der Anzahl von Rastern berechnet werden;
   einer CFM-Bildsyntheseeinrichtung (38) zum Berechnen von Dopplerverschiebungsdaten aus den reflektierten Echos, die für jedes Raster von der CFM-Abtasteinrichtung (12) abgetastet werden, und zum Erzeugen eines Farb-Strömung-Abbildung-Bildes als ein CFM-Teilbild aus den Dopplerverschiebungsdaten, die in der Anzahl von Rastern berechnet werden; und
   eine Anzeigeeinrichtung (46) zum Anzeigen des Farb-Strömung-Abbildung-Bildes auf dem Tomogramm-Bild,
   dadurch gekennzeichnet, daß:
   die Abtast-Steuerungseinrichtung (40) unabhängig eine erste Abtast-Teilbild-Geschwindigkeit, die von der B-Mode-Abtasteinrichtung (12) zum Abtasten des B-Mode-Teilbildes verwendet wird, und eine zweite Abtast-Teilbild-Geschwindigkeit steuert, die von der CFM-Abtasteinrichtung (12) zum Abtasten des CFM-Teilbildes verwendet wird, wobei die erste Abtast-Teilbild-Geschwindigkeit, die von der B-Mode-Abtasteinrichtung (12) zum Abtasten des B-Mode-Teilbildes verwendet wird, größer ist als die zweite Abtast-Teilbild-Geschwindigkeit, die von der CFM-Abtasteinrichtung (12) zum Abtasten des CFM-Teilbildes verwendet wird.

2. Gerät nach Anspruch 1, das außerdem eine Interpolationseinrichtung (88) zum Interpolieren eines Teilbildes des Farb-Strömung-Abbildung-Bildes mit Daten, die verwendet wurden, um ein früheres Teilbild des Farb-Strömung-Abbildung-Bildes zu erzeugen.

3. Gerät nach Anspruch 2, wobei die Anzeigeeinrichtung (46) abwechselnd das Farb-Strömung-Abbildung-Bild, das von der CFM-Bildsyntheseeinrichtung (38) erzeugt wird, und das interpolierte Farb-Strömung-Abbildung-Bild anzeigt, das von der Interpolationseinrichtung (88) erzeugt wird.

4. Gerät nach einem der vorhergehenden Ansprüche, wobei die Abtast-Steuerungseinrichtung (40) die CFM-Abtastraster zwischen den B-Mode-Abtastrastern verschachtelt.

5. Gerät nach einem der vorhergehenden Ansprüche, wobei die Abtast-Steuerungseinrichtung (40) unabhängig eine Periode zum Abtasten von N Teilbildern (N >= 2) durch die B-Mode-Abtasteinrichtung (12) und eine Periode zum Abtasten von M Teilbildern (1 <= M < N) durch die CFM-Abtasteinrichtung (12) so steuert, daß die Periode zum Abtasten von N Teilbildern durch die B-Mode-Abtasteinrichtung (12) und die Periode zum Abtasten von M Teilbildern durch die CFM-Abtasteinrichtung (12) gleich sind.

Revendications

1. Appareil à diagnostic par ultrasons pour afficher une image ultrasonore, image obtenue par des données fournies par plusieurs trames balayées par un transducteur de visualisation à ultrasons, comprenant :

   des moyens de transducteur (10) ;
   des moyens de balayage en mode B (12) pour balayer chaque trame en commandant les moyens de transducteur (10) de telle sorte que les moyens de transducteur (10) émettent une impulsion ultrasonore et reçoivent un écho réfléchi de chaque trame ;
   des moyens de représentation de flux de couleurs (CFM) (12) pour balayer chaque trame en commandant les moyens de transducteur (10) de telle sorte que les moyens de transducteur (10) émettent plusieurs impulsions

ultrasonores et reçoivent plusieurs échos réfléchis de chaque trame ;
des moyens de commande de balayage (40) pour commander les moyens de balayage en mode B (12) et les moyens de balayage de CFM (12) ;
des moyens de visualisation en mode B (24) pour calculer des données d'intensité de l'écho balayé par les moyens de balayage en mode B (12) pour chaque trame, et pour produire une image tomogramme sous forme d'une trame en mode B à partir des données d'intensité calculées dans la pluralité des trames ;
des moyens de visualisation par CFM (38) pour calculer une donnée dérivée Doppler à partir des échos réfléchis balayés par les moyens de balayage CFM (12) pour chaque trame, et pour produire une image par représentation de flux de couleurs sous forme d'une trame CFM à partir des données dérivées Doppler calculées dans la pluralité des trames ; et
des moyens d'affichage (46) pour afficher l'image de représentation du flux de couleurs sur l'image tomogramme, caractérisés en ce que :
les moyens de commande (40) commandent indépendamment une première vitesse de trame de balayage utilisée par les moyens de balayage en mode B (12) pour balayer la trame en mode B, et une seconde vitesse de trame de balayage utilisée par les moyens de balayage CFM (12) pour balayer la trame CFM, dans lesquels la première vitesse de trame de balayage utilisée dans les moyens de balayage en mode B (12) pour balayer la trame en mode B est supérieure à la seconde vitesse de trame de balayage utilisée par les moyens de balayage CFM (12) pour balayer la trame CFM.

2. Appareil selon la revendication 1, comprenant de plus des moyens d'interpolation (88) pour interpoler une trame de l'image de représentation de flux de couleurs à partir de données utilisées pour produire une trame antérieure de l'image de représentation de flux de couleurs.

3. Appareil selon la revendication 2, dans lequel les moyens d'affichage (46) affichent alternativement l'image de représentation des flux de couleurs produite par les moyens de visualisation par CFM (38) et l'image interpolée de représentation des flux de couleurs produite par les moyens d'interpolation (88).

4. Appareil selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens de commande de balayage (40) intercalent des trames de balayage CFM entre des trames de balayage en mode B.

5. Appareil selon l'une quelconque des revendications précédentes, dans lequel les moyens de commande de balayage (40) commandent indépendamment un temps de balayage de N trames (N>=2) par les moyens de balayage en mode B (12) et un temps de balayage de M trames (l<=M<N) par les moyens de balayage CFM (12) de telle sorte que le temps de balayage de N trames par les moyens de balayage en mode B (12) et le temps de balayage de M trames par les moyens de balayage CFM (12) soient égaux.

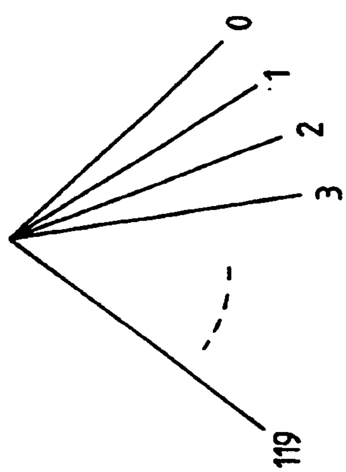

0
1
2
3
119

Fig.1(A).

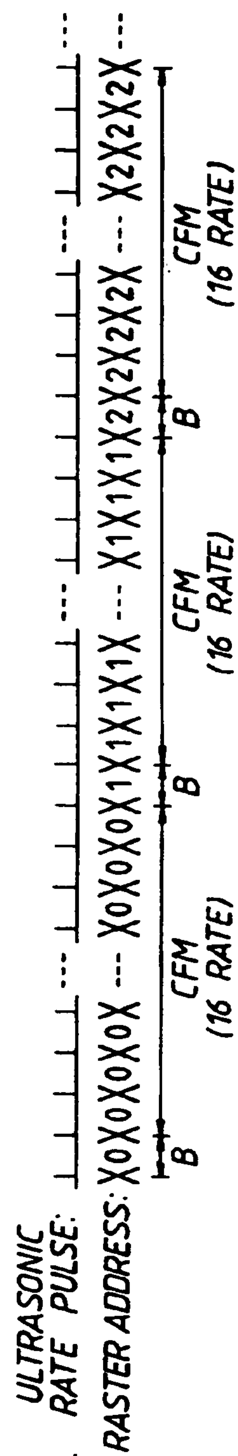

ULTRASONIC RATE PULSE:
RASTER ADDRESS: X0X0X0X0X0X --- X0X0X0X0X1X1X1X1X1X --- X1X1X1X2X2X2X2X2X --- X2X2X2X2X ---
B
CFM (16 RATE)
B
CFM (16 RATE)
B
CFM (16 RATE)

Fig.1(B).

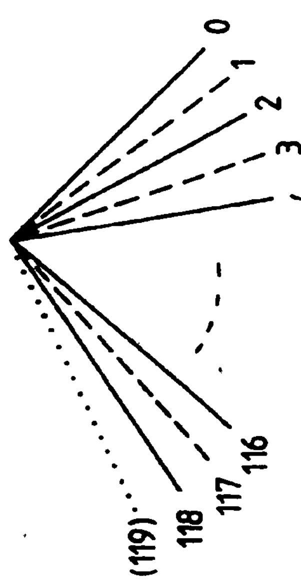

0
1
2
3
4
116
117
118
(119)

Fig.2(A)

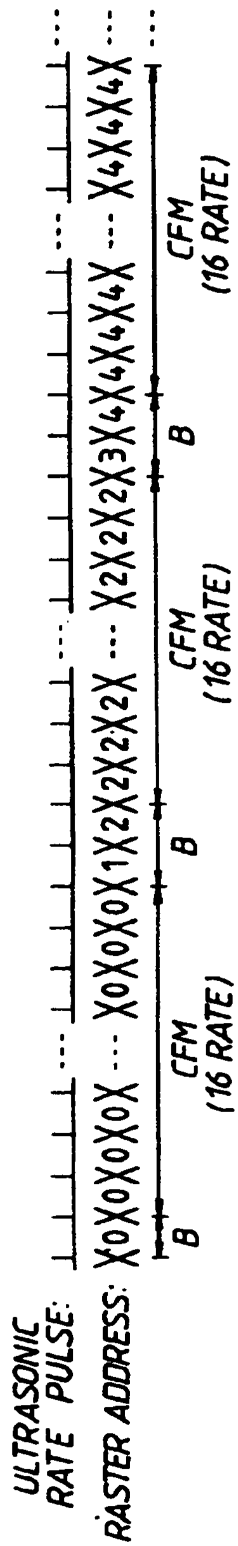

ULTRASONIC RATE PULSE:
RASTER ADDRESS:
X0X0X0X0X ... X0X0X0X1X2X2X2X2X2X ... X2X2X2X3X4X4X4X4X ... X4X4X4X
B
CFM (16 RATE)
B
CFM (16 RATE)
B
CFM (16 RATE)

Fig.2(B).

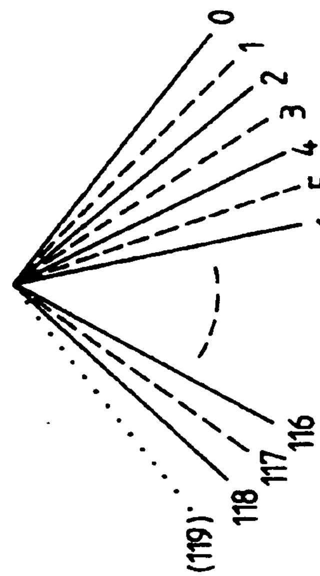

0
1
2
3
4
5
6
116
117
118
(119)

Fig. 3(A).

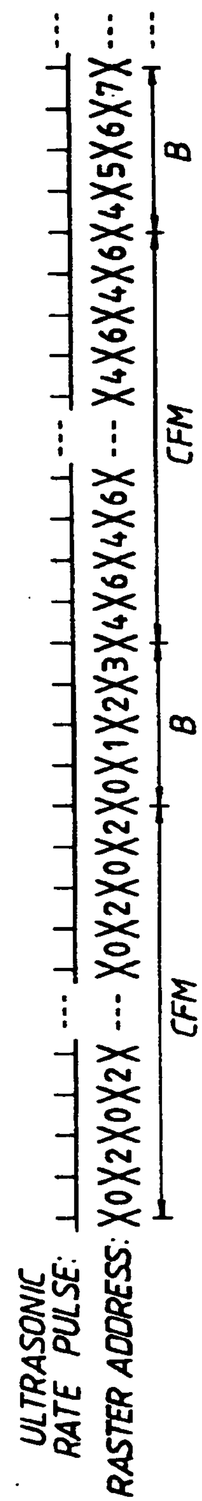

ULTRASONIC RATE PULSE:
RASTER ADDRESS:
X0X2X0X2X --- X0X2X0X2X0X1X2X3X4X6X4X6X --- X4X6X4X6X4X5X6X7X ---
CFM
B
CFM
B

Fig. 3(B).

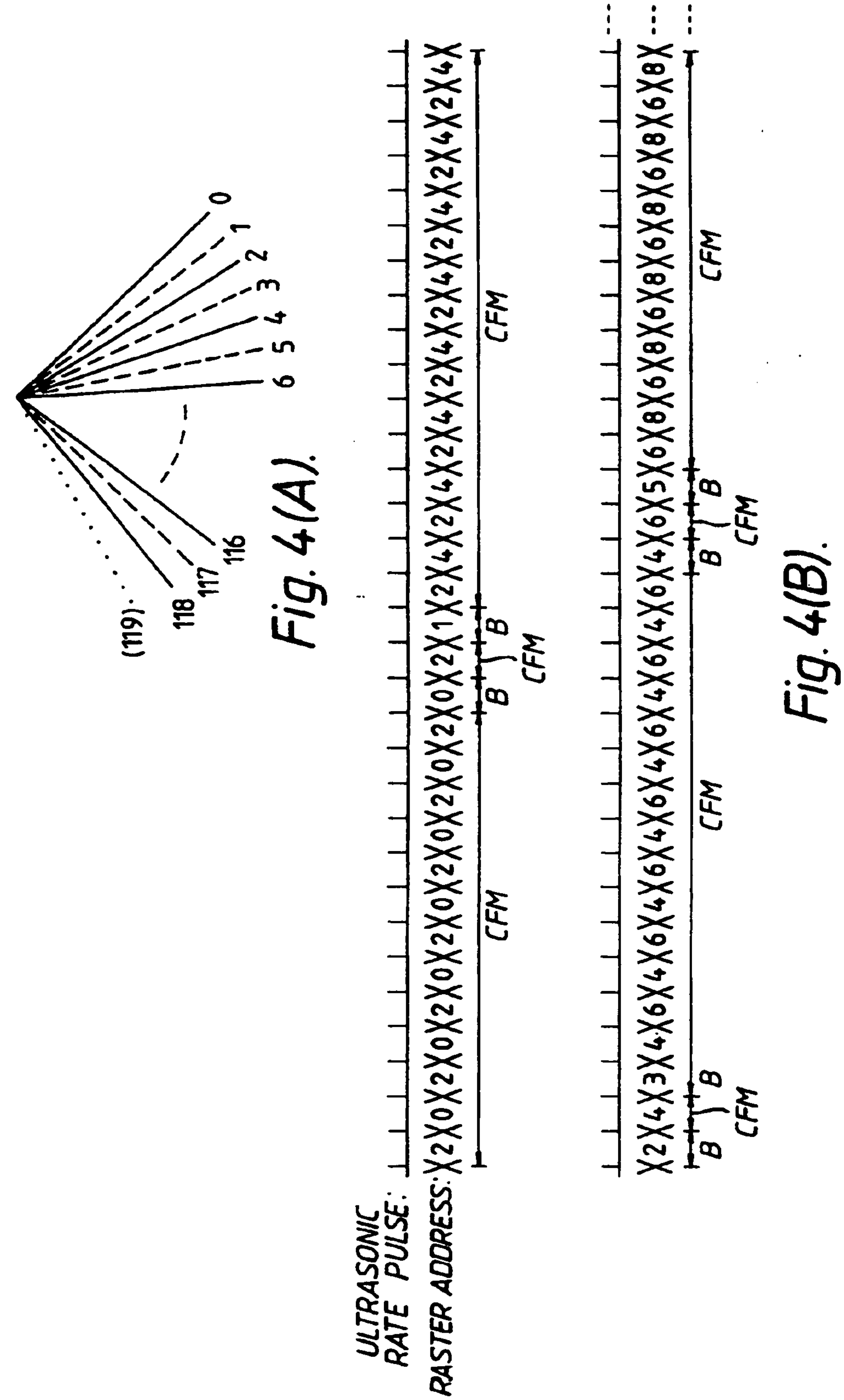

0
1
2
3
4
5
6
116
117
118
(119)
ULTRASONIC RATE PULSE:
RASTER ADDRESS:
CFM
B
CFM
B
CFM

Fig. 4(A).

Fig. 4(B).

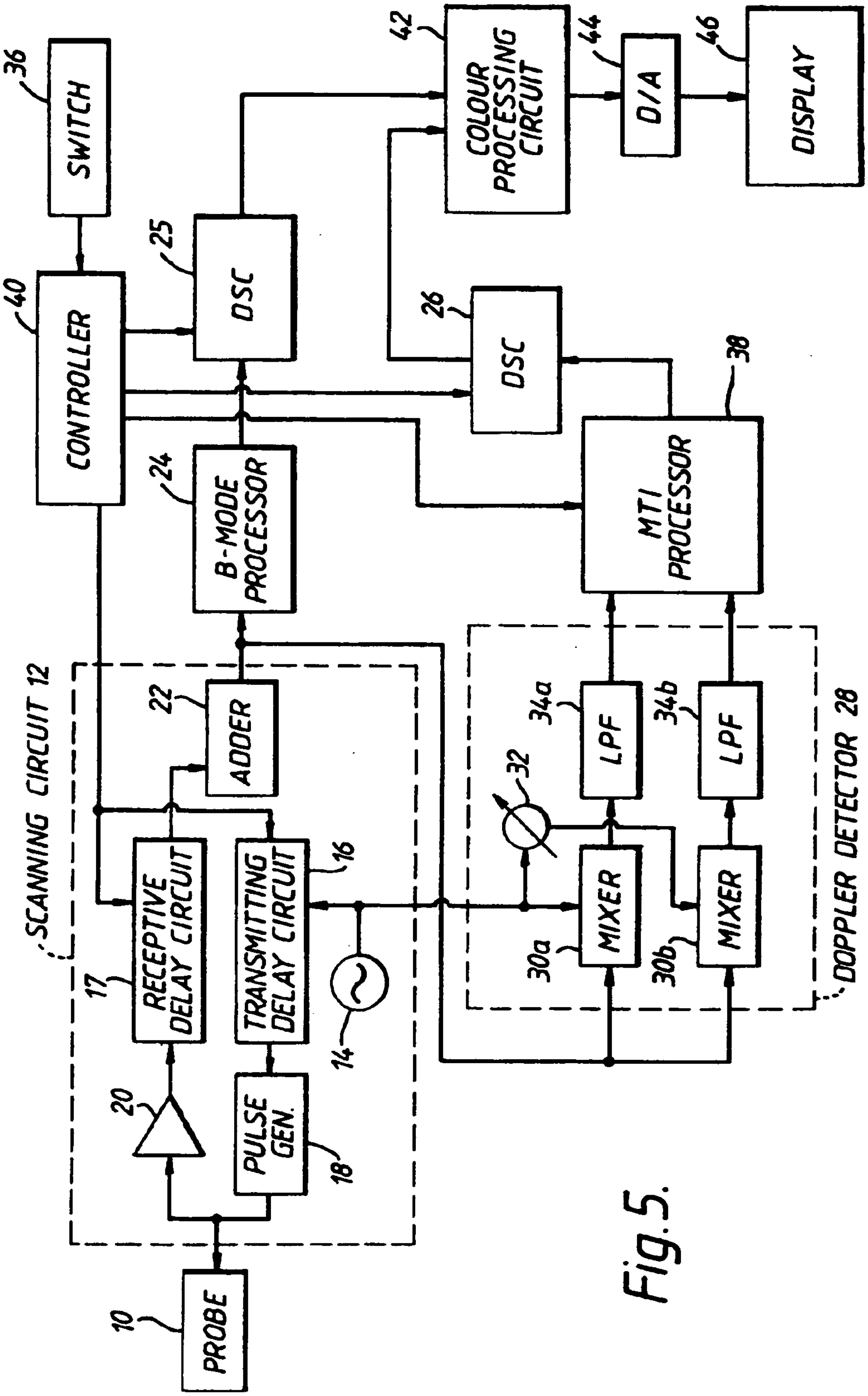

SWITCH
36
CONTROLLER
40
DSC
25
COLOUR PROCESSING CIRCUIT
42
D/A
44
DISPLAY
46
DSC
26
MTI PROCESSOR
38
B-MODE PROCESSOR
24
ADDER
22
SCANNING CIRCUIT 12
RECEPTIVE DELAY CIRCUIT
17
TRANSMITTING DELAY CIRCUIT
16
14
20
PULSE GEN.
18
PROBE
10
LPF
34a
LPF
34b
32
MIXER
30a
MIXER
30b
DOPPLER DETECTOR 28

Fig.5.

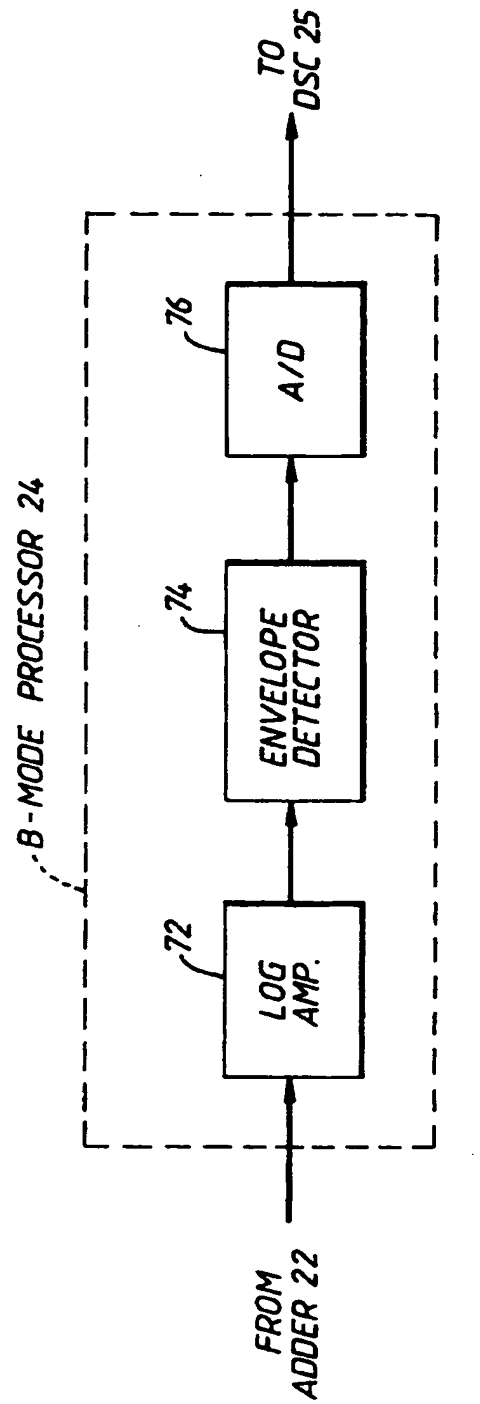

B-MODE PROCESSOR 24
FROM ADDER 22
72
LOG AMP.
74
ENVELOPE DETECTOR
76
A/D
TO DSC 25

Fig.6.

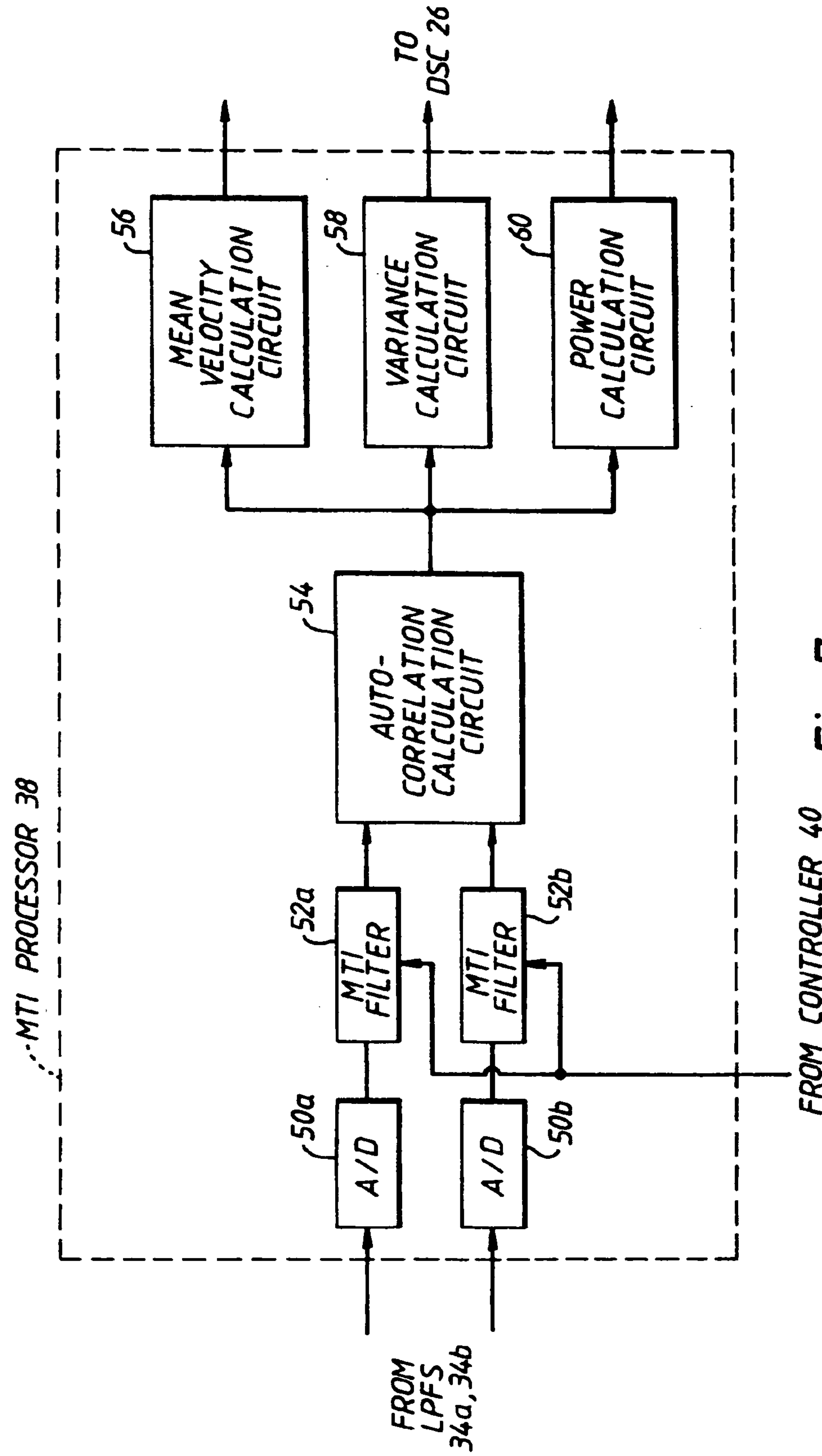

MTI PROCESSOR 38
TO DSC 26
56
MEAN VELOCITY CALCULATION CIRCUIT
58
VARIANCE CALCULATION CIRCUIT
60
POWER CALCULATION CIRCUIT
54
AUTO-CORRELATION CALCULATION CIRCUIT
52a
MTI FILTER
52b
MTI FILTER
50a
A/D
50b
A/D
FROM CONTROLLER 40
FROM LPFS 34a, 34b

Fig. 7.

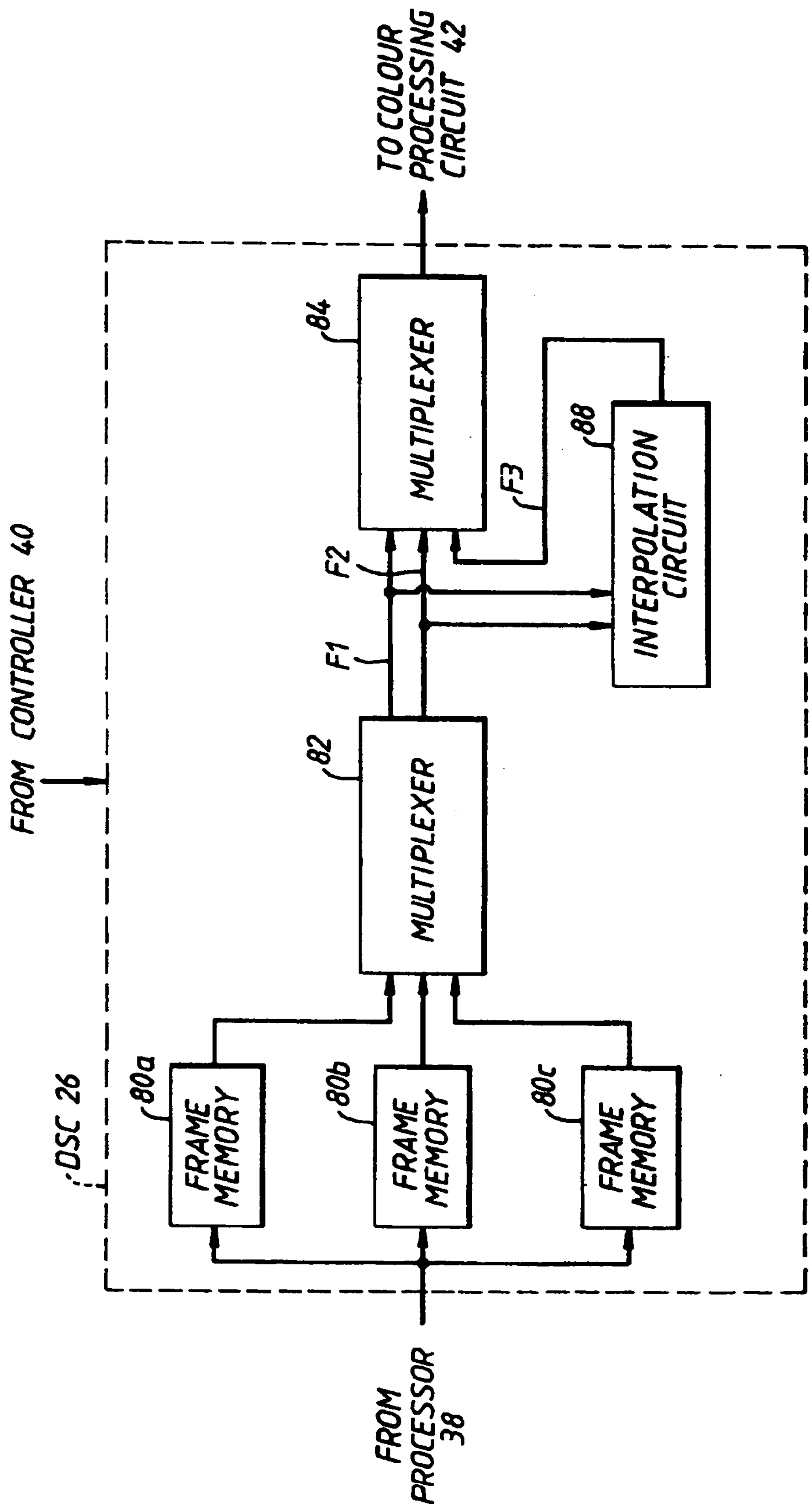

TO COLOUR PROCESSING CIRCUIT 42
FROM CONTROLLER 40
DSC 26
80a
FRAME MEMORY
80b
FRAME MEMORY
80c
FRAME MEMORY
82
MULTIPLEXER
F1
F2
F3
84
MULTIPLEXER
88
INTERPOLATION CIRCUIT
FROM PROCESSOR 38

Fig.8.

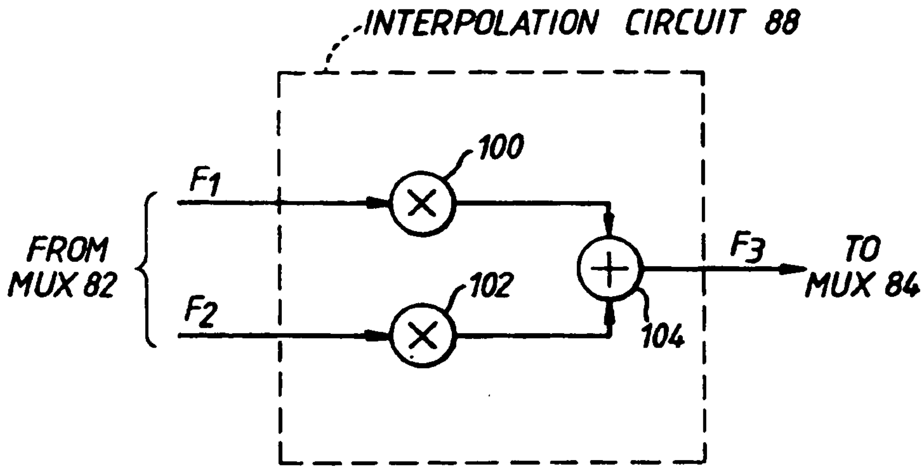

INTERPOLATION CIRCUIT 88
100
F1
FROM
MUX 82
F2
102
F3
TO
MUX 84
104

Fig. 9.

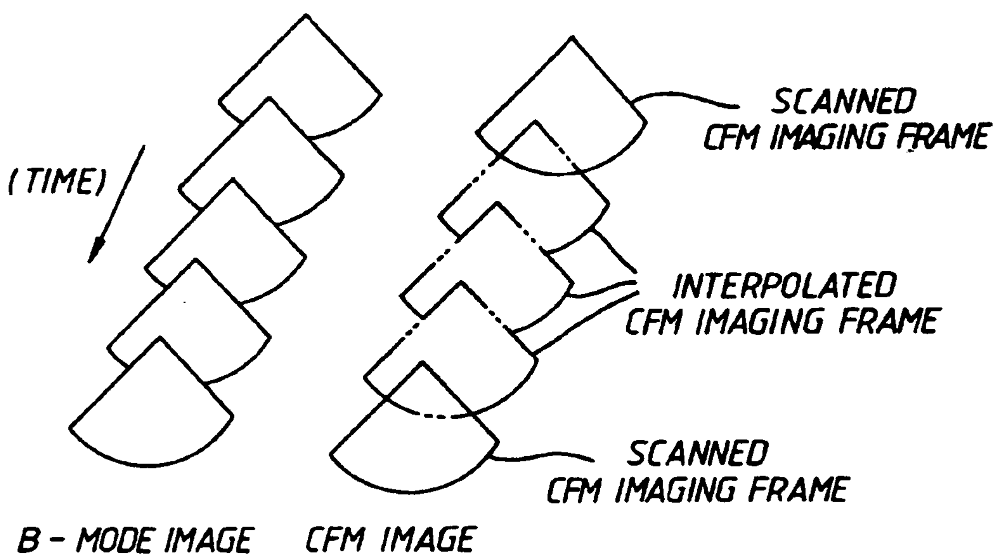

SCANNED
CFM IMAGING FRAME
(TIME)
INTERPOLATED
CFM IMAGING FRAME
SCANNED
CFM IMAGING FRAME
B - MODE IMAGE
CFM IMAGE

Fig. 11.

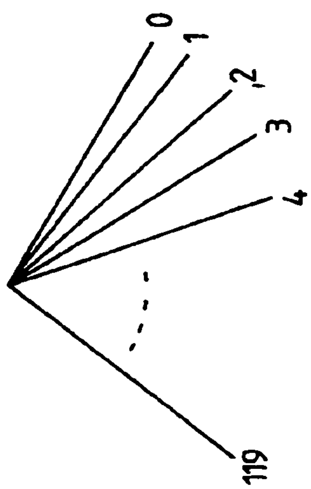


Fig.10(A).

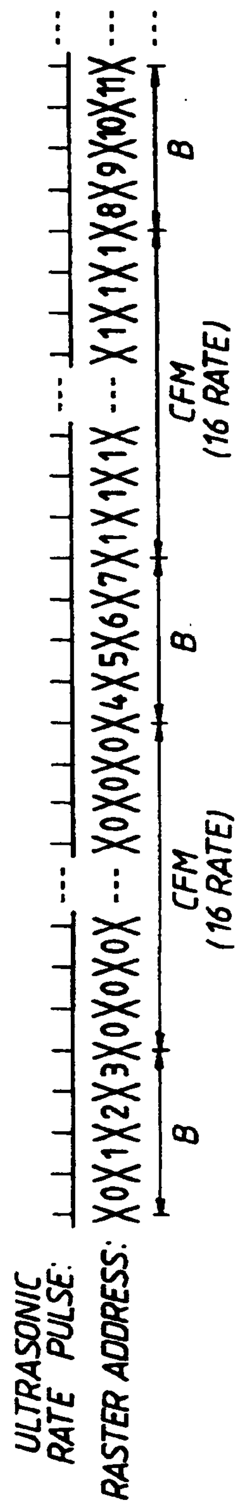


Fig.10.(B).

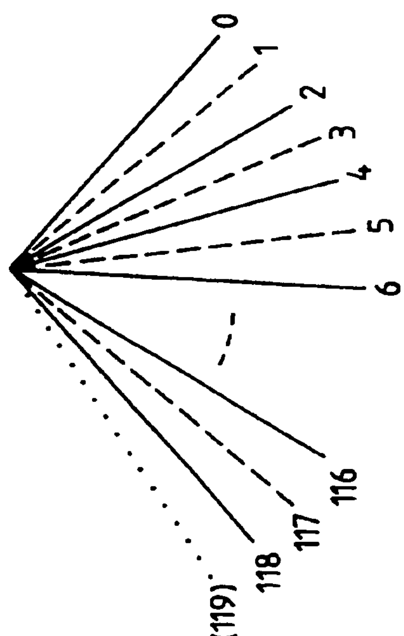


Fig. 12(A).

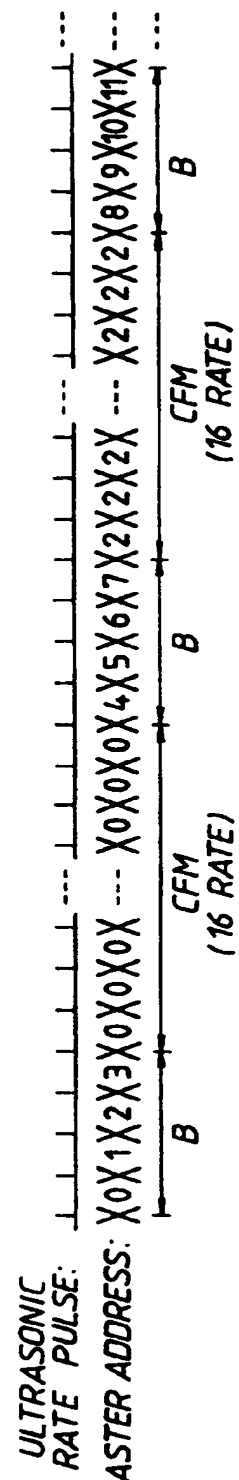


Fig.12(B).

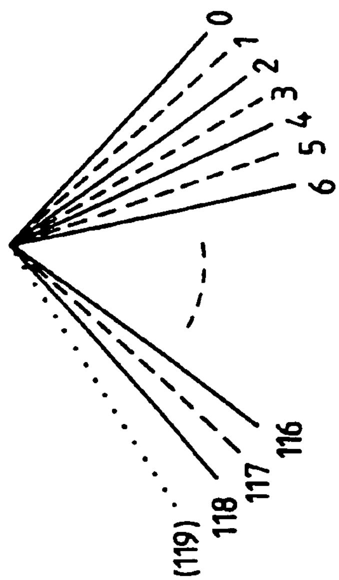


Fig.13(A).

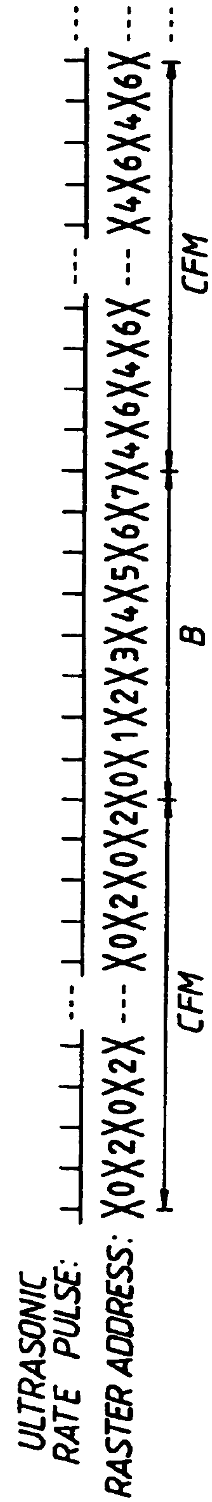


Fig.13(B).

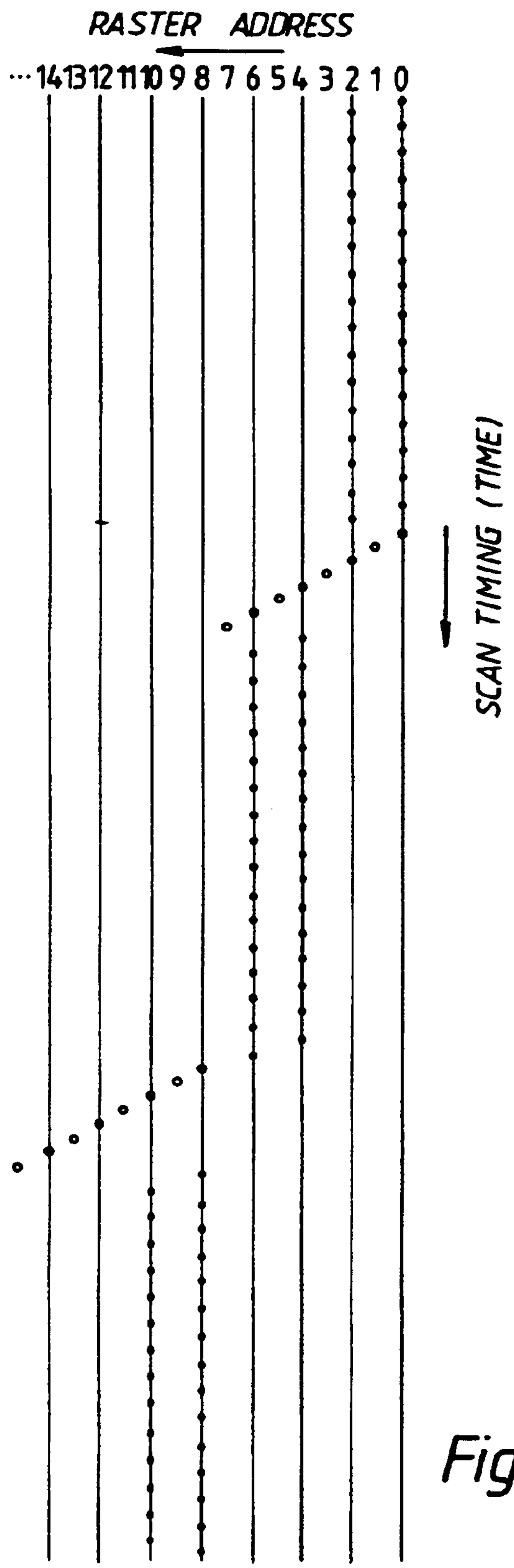
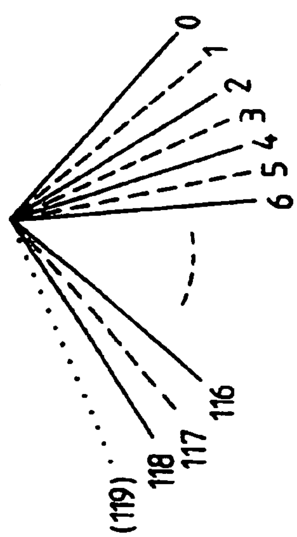


Fig.14.



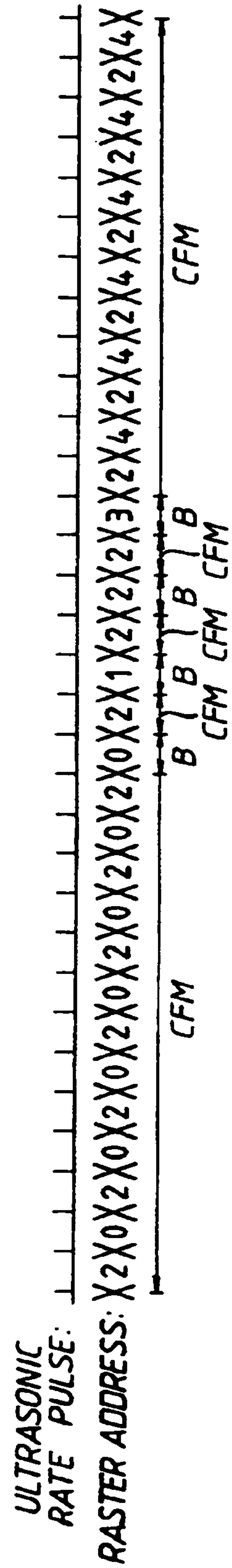


Fig.15(A)

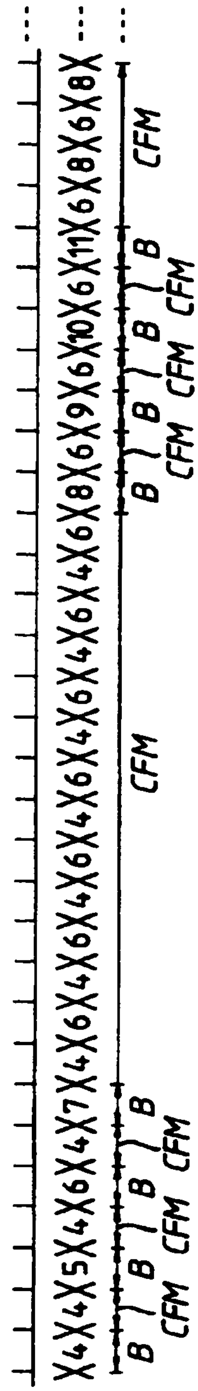


Fig.15(B).

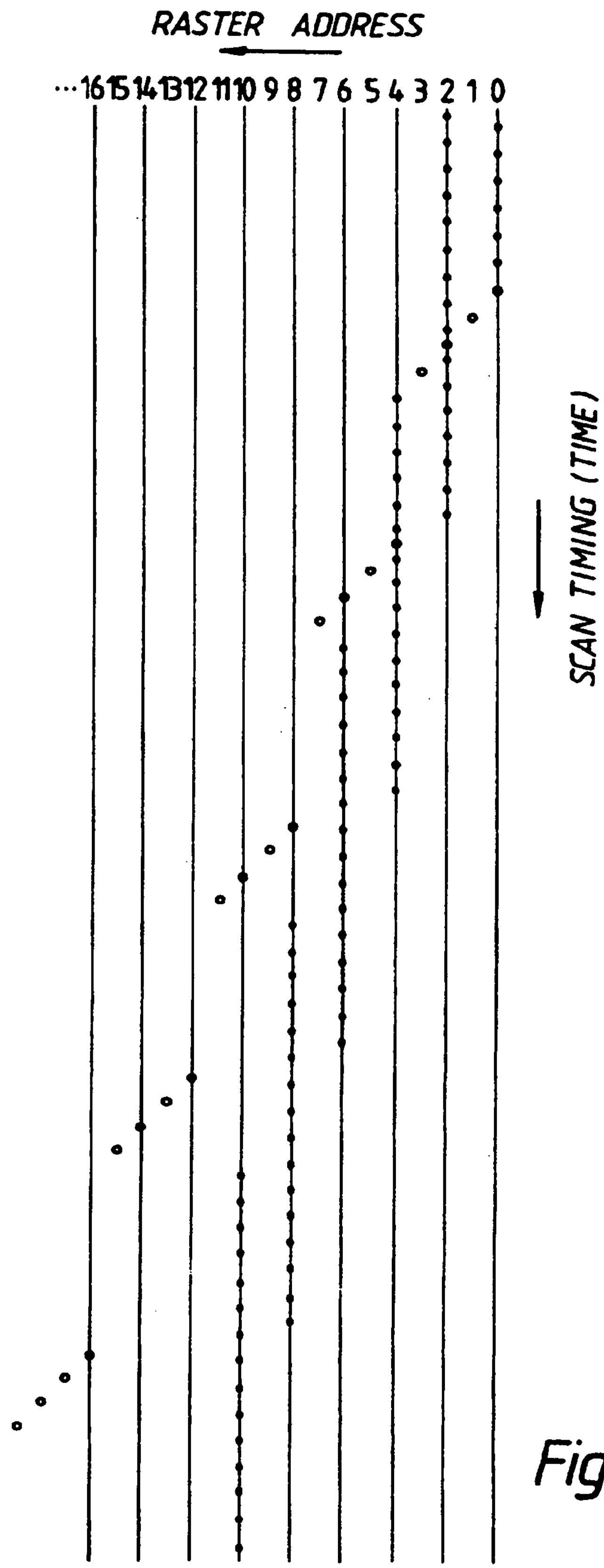

RASTER ADDRESS
···16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
SCAN TIMING (TIME)

Fig.16.

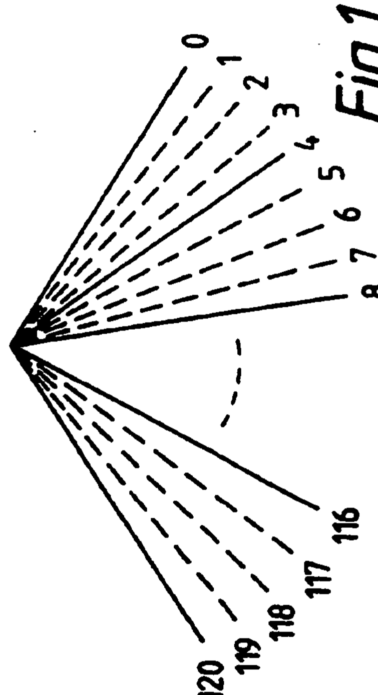


Fig.17(A).

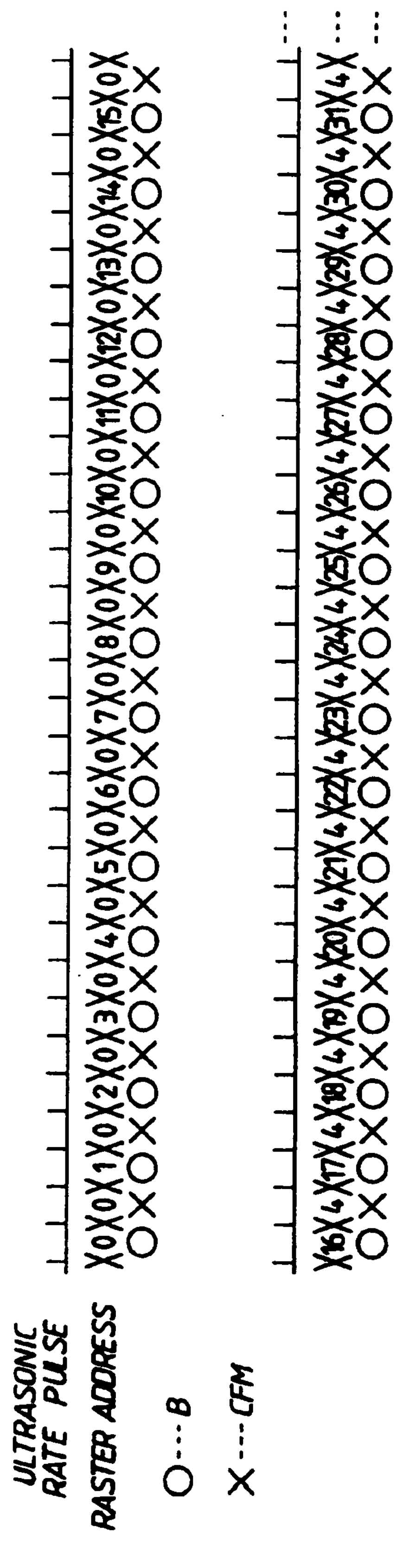


Fig.17(B).

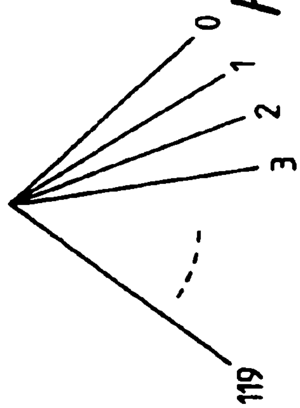


Fig.18(A).

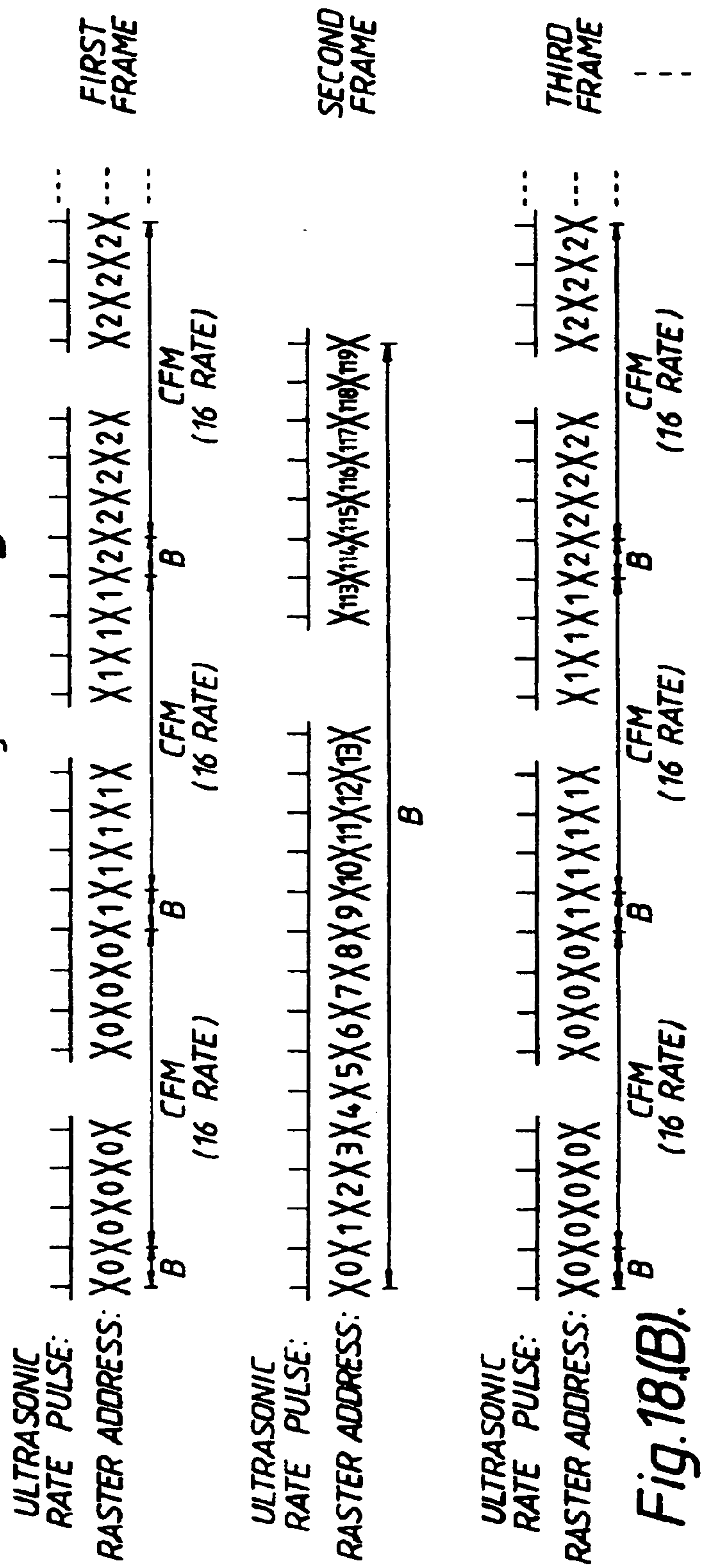


Fig.18(B).